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Engine Performance Characteristics

Powertrain Technology ACH4029

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1 Introduction and Objectives of the Test

1.1 Introduction

Dynamometer testing is a fundamental method used in automotive engineering to evaluate engine performance under controlled laboratory conditions. The primary aim of the test is to measure engine torque and calculate corresponding power across the operating speed range. This is achieved by applying a controlled load to the engine using an eddy current dynamometer, which enables precise regulation of engine operating conditions. As described by ([Heywood 1988](#)), direct measurement of brake torque provides an accurate representation of engine performance and allows detailed analysis of combustion efficiency and mechanical behaviour.

The dynamometer system shown also incorporates a range of supporting systems, including fuel supply, exhaust extraction, cooling, and sensor instrumentation. These systems ensure that the engine operates safely and consistently while allowing key parameters such as fuel consumption, air–fuel ratio, and temperature to be monitored. The controlled environment improves repeatability and enables accurate comparison between test runs, in accordance with standardised testing procedures such as those defined by SAE International ([Quigley, 2023](#)).

1.2 Objectives

The primary objective of the test is to measure the brake torque produced by the engine using the dynamometer and to calculate power output from the relationship between torque and engine speed. A further objective is to evaluate engine performance across its operating range by applying controlled load and monitoring key parameters such as speed, temperature, and fuel consumption.

The test also aims to ensure repeatability through controlled operating conditions and calibrated measurement systems, including the strain gauge-based torque measurement described in the video. Additionally, the setup enables analysis of engine behaviour under varying loads, providing data that can be used for performance evaluation, calibration, and comparison with future tests ([Martyr and Plint, 2012](#)).

2 Equipment used for Testing and Methodology

2.1 Equipment Testing and Methodology

The testing described is conducted in an engine dynamometer test cell, where the engine is mounted independently and directly coupled to a dynamometer. A driveshaft is bolted directly to the crankshaft, ensuring that the rotational speed of the engine is identical to that of the dynamometer. This direct mechanical coupling eliminates drivetrain losses such as those from the gearbox, differential, and tyres, allowing highly accurate measurement of true engine output under controlled conditions.

The dynamometer used is a Shank W230 eddy current dynamometer, capable of operating at speeds up to 10,000 rpm and applying a maximum load of 230 kW. It operates based on electromagnetic induction: the engine drives an internal rotor, while an electrical current applied to the outer casing generates a magnetic field that resists rotation. This resistance produces a controllable braking force on the engine. The reaction force causes the dynamometer casing to attempt to rotate, and this movement is restrained and measured.

Torque measurement is achieved using a strain gauge system attached to the dynamometer casing. This system outputs a voltage signal, typically in the range of 0 to 10 volts, proportional to the applied load. Since this voltage does not directly correspond to torque, a calibration process is required. Known masses are applied to a fixed-length lever arm, creating known torque values. By recording the corresponding voltage outputs, a calibration curve is generated, enabling accurate conversion of voltage into torque in newton metres.

Engine speed is measured directly from the dynamometer shaft, ensuring precise synchronisation. Additional instrumentation includes coolant temperature sensors, a fuel flow meter, and a lambda sensor for monitoring air–fuel ratio. These sensors provide real-time data to a computerised acquisition system for detailed analysis.

The fuel system is configured to measure only consumed fuel, improving accuracy. Testing is conducted by varying dynamometer load, enabling controlled, repeatable engine performance evaluation.



Figure 1 (Honda VTEC 1.6 Engine attached to Dynamometer via Drive Shaft)

3 Spreadsheet data results table

							Baro	Humidity	Ambient temp	Displacement	Length	CF		p (Fuel Density)	LHV
							mBar	%	Deg C	Litres	M			kg/L	KJ
							1018.9	46	27	1.6	0.815	1.006263842		0.74	44000
Load	Dyno Speed	Fuel Flow Rate	Lambda	Torque	Power	BMEP	Corrected Power	Fuel Flow Rate	Mass Flow Rate	SFC	Fuel Flow Rate	Overall Thermal Efficiency			
Newtons	rpm	l/min	Lambda	Nm	Kw	mBar	Kw	l/h	g/h	g/kwh	KG/S	%			
102.275	1000	0.0704	1.2658	83.35413	8.728823558	654.6618	8.783499527	4.224	3125.76	355.86727	0.000868267	22.99%			
102.756	1050	0.0724	1.26783	83.74614	9.208369037	657.7406	9.266048802	4.344	3214.56	346.918095	0.000892933	23.58%			
103.689	1100	0.0737	1.27344	84.50654	9.734454016	663.7128	9.795429095	4.422	3272.28	334.061935	0.000908967	24.49%			
104.209	1150	0.0728	1.28476	84.93034	10.22796647	667.0413	10.29203283	4.368	3232.32	314.060405	0.000897867	26.05%			
105.811	1200	0.0744	1.29181	86.23597	10.83673096	677.2957	10.90461053	4.464	3303.36	302.932415	0.0009176	27.01%			
107.51	1250	0.07895	1.29729	87.62065	11.46951626	688.171	11.5413595	4.737	3505.38	303.723318	0.000973717	26.94%			
109.488	1300	0.079	1.29895	89.23272	12.14775716	700.8321	12.22384879	4.74	3507.6	286.947267	0.000974333	28.51%			
111.797	1350	0.0796	1.29469	91.11456	12.88101675	715.612	12.9617014	4.776	3534.24	272.667908	0.000981733	30.01%			
114.268	1400	0.0835	1.2855	93.12842	13.65333947	731.4289	13.73886183	5.01	3707.4	269.847681	0.001029833	30.32%			
115.783	1450	0.0847	1.27818	94.36315	14.32844388	741.1264	14.41819499	5.082	3760.68	260.828766	0.001044633	31.37%			
116.985	1500	0.08865	1.2795	95.34278	14.97640808	748.8204	15.07021792	5.319	3936.06	261.181359	0.00109335	31.33%			
117.788	1550	0.0932	1.27766	95.99722	15.58184832	753.9604	15.67945056	5.592	4138.08	263.917411	0.001149467	31.00%			
118.471	1600	0.0959	1.28235	96.55387	16.17775536	758.3323	16.27909026	5.754	4257.96	261.560071	0.001182767	31.28%			
118.772	1650	0.09875	1.29028	96.79918	16.7256976	760.259	16.83046472	5.925	4384.5	260.509741	0.001217917	31.41%			
118.656	1700	0.10005	1.29942	96.70464	17.21570657	759.5165	17.32354303	6.003	4442.22	256.426759	0.00123395	31.91%			
118.861	1750	0.10305	1.31053	96.87172	17.75266898	760.8287	17.86386889	6.183	4575.42	256.127048	0.00127095	31.94%			
119.584	1800	0.1093	1.3149	97.46096	18.37095816	765.4566	18.48603093	6.558	4852.92	262.518224	0.001348033	31.17%			
119.934	1850	0.11415	1.31849	97.74621	18.93652447	767.6969	19.05513986	6.849	5068.26	265.97863	0.00140785	30.76%			
120.176	1900	0.11745	1.31892	97.94344	19.4875648	769.246	19.60963182	7.047	5214.78	265.929521	0.00144855	30.77%			
120.948	1950	0.12055	1.31484	98.57262	20.12887622	774.1875	20.25496032	7.233	5352.42	264.252307	0.001486783	30.96%			
122.157	2000	0.12555	1.31653	99.55796	20.85136934	781.9264	20.98197901	7.533	5574.42	265.67656	0.00154845	30.80%			
122.845	2050	0.12785	1.32098	100.1187	21.49302641	786.3302	21.62765533	7.671	5676.54	262.466731	0.001576817	31.17%			
123.796	2100	0.1309	1.32287	100.8937	22.18769227	792.4176	22.32667246	7.854	5811.96	260.314653	0.001614433	31.43%			
124.794	2150	0.13435	1.32164	101.7071	22.89909885	798.8058	23.04253518	8.061	5965.14	258.875161	0.001656983	31.61%			
125.137	2200	0.1377	1.31652	101.9867	23.49603858	801.0013	23.64321405	8.262	6113.88	258.589208	0.0016983	31.64%			
126.028	2250	0.14105	1.30465	102.7128	24.20113806	806.7046	24.35272015	8.463	6262.62	257.162953	0.001739617	31.82%			
126.66	2300	0.14495	1.29646	103.2279	24.86300094	810.75	25.01873884	8.697	6435.78	257.238386	0.001787717	31.81%			
126.822	2350	0.14985	1.28229	103.3599	25.43599241	811.787	25.59531944	8.991	6653.34	259.94362	0.00184815	31.48%			
126.69	2400	0.1537	1.27304	103.2524	25.95014594	810.9421	26.11269354	9.222	6824.28	261.339566	0.001895633	31.31%			
126.552	2450	0.15565	1.26984	103.1399	26.46191829	810.0587	26.62767156	9.339	6910.86	259.536775	0.001919683	31.52%			
126.438	2500	0.1596	1.27446	103.047	26.97763366	809.329	27.14661729	9.576	7086.24	261.035838	0.0019684	31.34%			
126.239	2550	0.1626	1.27876	102.8848	27.4738772	808.0552	27.64596922	9.756	7219.44	261.138973	0.0020054	31.33%			
126.161	2600	0.16805	1.27634	102.8212	27.99527239	807.5559	28.17063034	10.083	7461.42	264.865213	0.002072617	30.89%			
125.847	2650	0.17145	1.28027	102.5653	28.4626261	805.546	28.64091149	10.287	7612.38	265.786932	0.00211455	30.78%			
124.911	2700	0.17465	1.28371	101.8025	28.78396885	799.5547	28.96426708	10.479	7754.46	267.725055	0.002154017	30.56%			
123.927	2750	0.1784	1.2812	101.0005	29.08605741	793.2561	29.26824787	10.704	7920.96	270.633214	0.002200267	30.23%			
123.689	2800	0.18005	1.27448	100.8065	29.55801985	791.7327	29.7431666	10.803	7994.22	268.775013	0.002220617	30.44%			
123.589	2850	0.1831	1.26036	100.562	30.01287029	789.8124	30.20086615	10.986	8129.64	269.185657	0.002258233	30.39%			
122.319	2900	0.1879	1.2531	99.85299	30.3240824	784.2435	30.51402765	11.274	8342.76	273.407368	0.002317433	29.93%			
121.837	2950	0.19255	1.23943	99.29716	30.67520258	779.878	30.86734719	11.553	8549.22	276.966464	0.002374783	29.54%			
121.709	3000	0.199	1.22735	99.19284	31.16234817	779.0587	31.35754419	11.94	8835.6	281.769514	0.002454333	29.04%			
121.123	3050	0.20605	1.2193	98.71525	31.52918066	775.3077	31.72667446	12.363	9148.62	288.357357	0.002541283	28.37%			
121.124	3100	0.21005	1.20692	98.71606	32.04631705	775.3141	32.24750511	12.603	9326.22	289.21157	0.002590617	28.29%			
120.851	3150	0.21605	1.19274	98.49357	32.48979932	773.5667	32.69331028	12.963	9592.62	293.412319	0.002664617	27.89%			
120.596	3200	0.21795	1.18481	98.28574	32.9358676	771.9344	33.14217266	13.077	9676.98	291.983875	0.00268805	28.02%			
120.84	3250	0.22305	1.17378	98.4846	33.51817038	773.4962	33.72812229	13.383	9903.42	293.624997	0.00275095	27.86%			
121.633	3300	0.2255	1.16118	99.1309	34.25717806	778.5722	34.4717596	13.53	10012.2	290.446444	0.002781167	28.17%			
122.181	3350	0.2285	1.15104	99.57752	34.9329055	782.08	35.15171969	13.71	10145.4	288.617459	0.002818167	28.35%			
122.933	3400	0.2342	1.14117	100.1904	35.67250634	786.8935	35.89595327	14.052	10398.48	289.683907	0.00288467	28.24%			
123.475	3450	0.23605	1.12669	100.6321	36.35669163	790.3629	36.58442419	14.163	10480.62	286.477654	0.002911283	28.56%			
123.428	3500	0.24195	1.11975	100.5938	36.86956069	790.062	37.10050578	14.517	10742.58	289.553465	0.00298405	28.26%			
124.205	3550	0.24545	1.10622	101.2271	37.63168449	795.0356	37.86740341	14.727	10897.98	287.793168	0.003027217	28.43%			
124.066	3600	0.25505	1.09697	101.1138	38.11900078	794.1458	38.35777217	15.303	11324.22	295.226218	0.003145617	27.71%			
123.967	3650	0.25755	1.09401	101.0331	38.61759135	793.5122	38.85948583	15.453	11435.22	294.271006	0.00317645	27.80%			
123.815	3700	0.26445	1.09559	100.9092	39.09860053	792.5392	39.34350797	15.867	11741.58	298.437547	0.00326155	27.42%			
123.767	3750	0.2651	1.09808	100.8701	39.6115976	792.232	39.85971838	15.906	11770.44	295.296617	0.003269567	27.71%			
123.509	3800	0.2693	1.09907	100.6598	40.05607843	790.5805	40.30698337	16.158	11956.92	296.646363	0.003321367	27.58%			
122.672	3850	0.27375	1.10533	99.97768	40.30810694	785.2229	40.56059054	16.425	12154.5	299.662797	0.00337625	27.30%			
122.157	3900	0.2759	1.11704	99.55796	40.6601702	781.9264	40.91485907	16.554	12249.96	299.401251	0.003402767	27.33%			
121.184	3950	0.28285	1.12259	98.76496	40.85343758	775.6982	41.10933705	16.971	12558.54	305.491183	0.003488483	26.78%			
120.004	4000	0.28455	1.12461	97.80326	40.96773375	768.145	41.22434915	17.073	12634.02	306.469848	0.00350945	26.70%			
118.734	4050	0.2871	1.1222	96.76821	41.04085018	760.0157	41.2972357	17.226	12747.24	308.665398	0.0035409	26.51%			
117.442	4100	0.28895	1.12394	95.71523	41.09542933	751.7457	41.35284459	17.337	12829.38	310.241777	0.003563717	26.37%			
116.5	4150	0.29305	1.12233	94.9475	41.26294764	745.7159	41.52141221	17.583	13011.42	313.366509	0.003614283	26.11%			
115.931	4200	0.2949	1.12179	94.48377	41.55613028	742.0738	41.8164313	17.694	13093.56	313.1					

4 Graphical Results

4.1 SFC Against Engine Speed

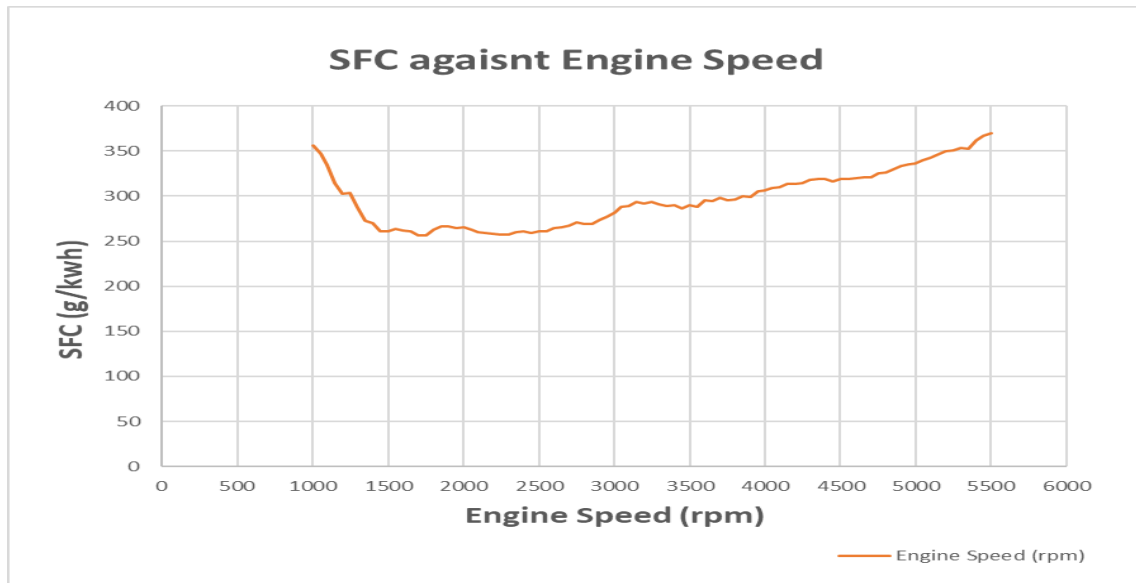


Figure 3 (SFC Against Engine Speed)

Specific Fuel Consumption (SFC), represents engine efficiency and is defined as:

$$SFC = \frac{\dot{m}_f}{P}$$

where $\dot{m}_f$ is fuel mass flow rate and P is brake power.

Specific Fuel Consumption (SFC), represents engine efficiency and is defined as:

$$SFC = \frac{\dot{m}_f}{P}$$

where $\dot{m}_f$ is fuel mass flow rate and P is brake power.

SFC is a key indicator of how effectively an engine converts fuel into useful work. Lower SFC values indicate higher efficiency, as less fuel is required to produce a given power output. The variation of SFC with engine speed typically follows a characteristic trend, as shown in Figure 3.

At low engine speeds, SFC is relatively high. This is because the engine produces low brake power while still consuming fuel to overcome internal losses such as mechanical friction and pumping losses. These losses are proportionally large compared to the useful output, resulting in poor efficiency and a higher fuel-to-power ratio (Xin, 2013).

As engine speed increases, SFC decreases, reaching a minimum in the mid-speed range (approximately 2000–3000 rpm). In this region, the engine operates near its optimal efficiency. Volumetric efficiency improves, allowing more air–fuel mixture to enter the cylinders, and combustion becomes complete and more stable. As a result, brake power increases more rapidly than

fuel consumption, leading to a reduction in SFC. This range is often considered the most economical operating condition for the engine.

At higher engine speeds, SFC increases again. This is due to increased mechanical friction, higher thermal losses, and reduced time available for complete combustion. Additionally, volumetric efficiency may decrease as airflow becomes restricted at higher speeds. Engines may also require richer mixtures to maintain stable operation, further increasing fuel consumption ([Ferguson and Kirkpatrick, 2016](#)).

Overall, the trend demonstrates a U-shaped relationship between SFC and engine speed, reflecting the balance between fuel consumption and power output, with maximum efficiency occurring at mid-range speeds.

4.2 Torque Against Engine Speed

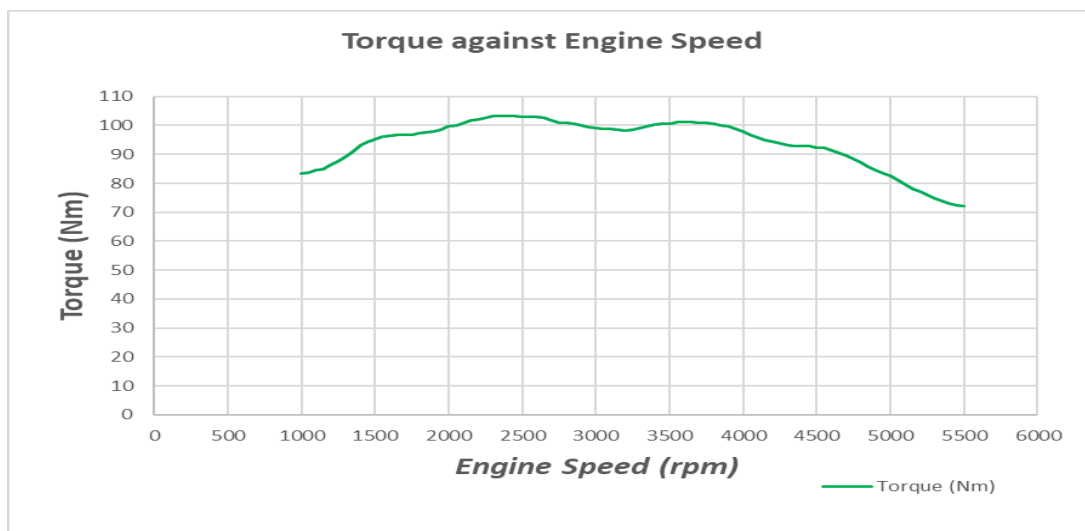


Figure 4 (Torque Against Engine Speed)

Torque is determined from dynamometer measurements using the calibrated relationship between force and moment arm, expressed as:

$$T = F \times r$$

where F is the force measured by the strain gauge and r is the calibrated arm length. This relationship is used in the data acquisition system to convert measured load into torque.

At low engine speeds, torque is relatively low due to reduced volumetric efficiency and less effective air–fuel mixing. Limited airflow into the cylinders restricts combustion efficiency, resulting in lower force applied to the crankshaft. Additionally, combustion may be less stable at low speeds, further contributing to reduced torque output.

As engine speed increases, torque rises and reaches a peak in the mid-range, typically around 3000 rpm. This is due to improved cylinder filling, increased turbulence, and more efficient combustion. Airflow into the engine becomes more effective, allowing a greater mass of air–fuel mixture to enter the cylinders. This leads to higher combustion pressures and greater force acting on the pistons, increasing torque. The peak torque region represents the engine's most effective operating range in terms of force production ([Stone, 2012](#)).

At higher engine speeds, torque begins to decrease. This decline is caused by reduced volumetric efficiency, as there is less time available for air to enter the cylinders. Increased mechanical friction and heat losses also reduce effective force transmission. Furthermore, shorter combustion duration limits the completeness of combustion. As a result, the force generated during each cycle decreases, leading to a reduction in torque output.

Overall, the trend demonstrates that torque is strongly influenced by airflow, combustion efficiency, and mechanical losses across the engine speed range.

4.3 Brake Power Against Engine Speed

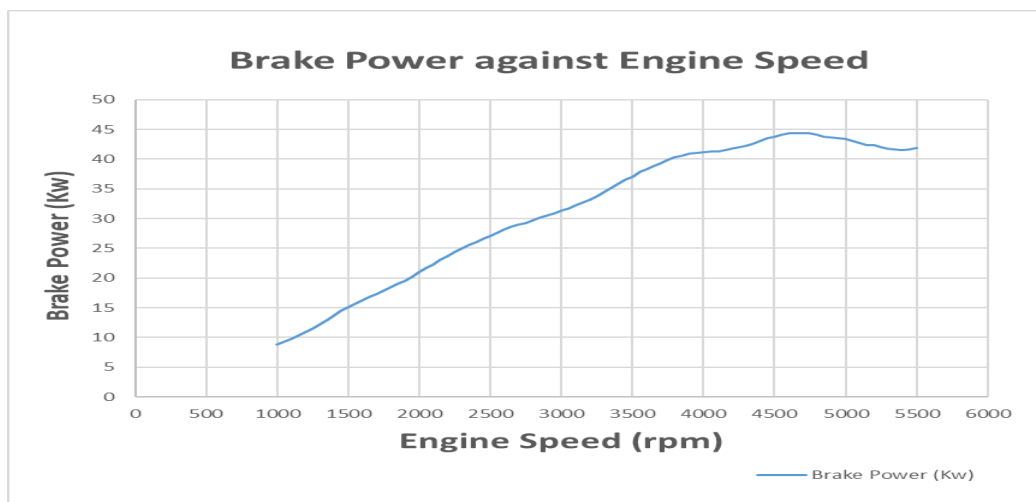


Figure 5 (Brake Power Against Engine Speed)

Brake power is a key parameter used to evaluate engine performance and represents the useful power output available at the crankshaft. It is calculated from torque and engine speed, with corrected power accounting for atmospheric conditions. In the Excel calculations, brake power is determined using:

$$P = \frac{2\pi NT}{60}$$

where N is engine speed (rpm) and T is torque (Nm). This relationship shows that power is directly proportional to both torque and rotational speed, meaning that increases in either variable will result in higher brake power output.

The correction factor is calculated from:

$$CF = \frac{P_a}{P_{ref}} \times \frac{T_{ref}}{T_a}$$

where P_a is the measured ambient pressure and T_a is the ambient temperature in Kelvin. The terms P_{ref} and T_{ref} represent the reference pressure and reference temperature. This correction ensures that

measured engine performance can be standardised and compared under consistent atmospheric conditions, accounting for variations in air density that affect combustion.

This value is then adjusted using a correction factor:

$$P_{corr} = P \times CF$$

At low engine speeds, brake power is low due to both reduced torque and rotational speed. As engine speed increases, brake power rises steadily because power is directly proportional to speed. Improvements in volumetric efficiency and combustion quality at moderate speeds also contribute to increased torque, further enhancing power output.

Maximum corrected brake power typically occurs at higher engine speeds (approximately 4500–5000 rpm), where the combined effect of high torque and high speed produces the greatest power. However, beyond this point, brake power begins to decrease slightly. This is due to a more rapid decline in torque at high speeds, caused by increased mechanical friction, reduced volumetric efficiency, and shorter combustion duration.

Furthermore, the trend demonstrates that brake power is strongly influenced by both engine speed and torque, with peak performance occurring where their product is maximised ([Prof A. O Odukwe, T. Onah and Tor, 2016](#)).

4.4 Thermal Efficiency Against Engine Speed

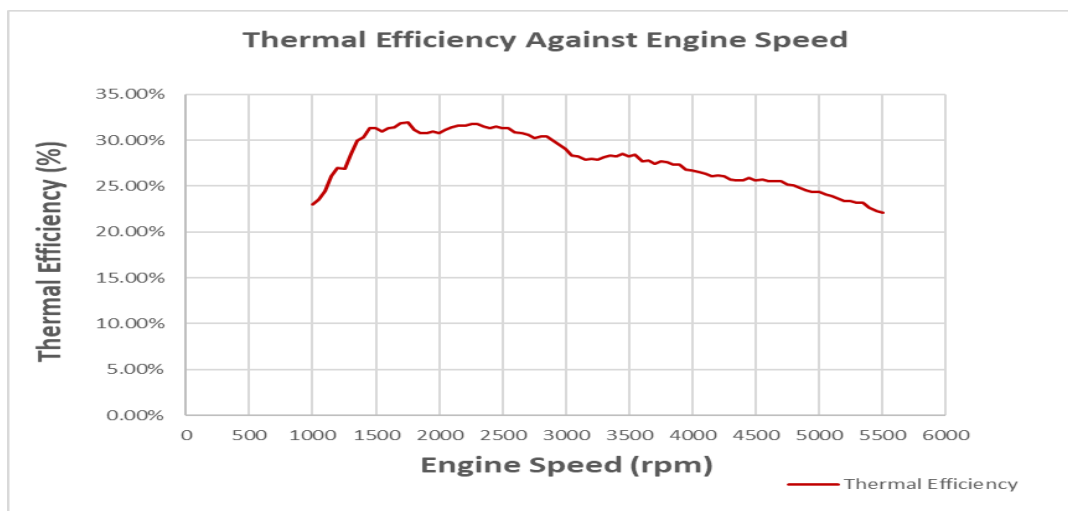


Figure 6 (Thermal Efficiency Against Engine Speed)

Thermal efficiency represents the effectiveness of converting fuel energy into useful work and is calculated using:

$$\eta_{th} = \frac{P}{\dot{m}_f \times CV}$$

where P is brake power, $\dot{m}_f$ is fuel mass flow rate, and CV is the calorific value of the fuel.

At low engine speeds, thermal efficiency is relatively low due to poor air–fuel mixing and incomplete combustion. As engine speed increases, efficiency improves and reaches a peak in the mid-range (approximately 1500–2500 rpm), where volumetric efficiency and combustion conditions are optimised.

At higher engine speeds, thermal efficiency decreases due to reduced time for complete combustion, increased heat losses, and rising mechanical friction. Additionally, increased fuel consumption relative to power output reduces overall efficiency.

This trend reflects the balance between combustion effectiveness and mechanical losses across the engine speed range ([Rasam et al., 2020](#)).

4.5 BMEP Against Engine Speed

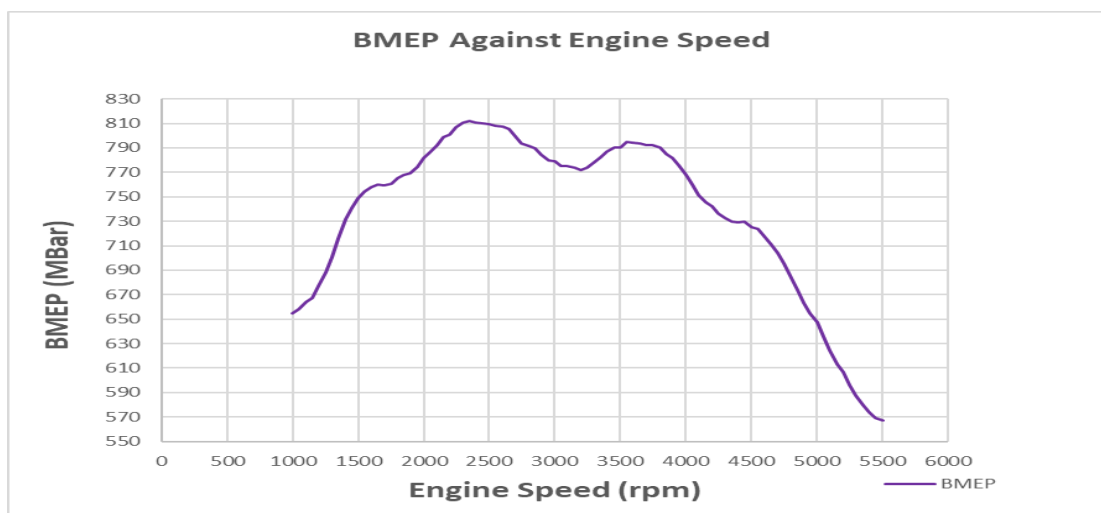


Figure 7 (BMEP Against Engine Speed)

Brake Mean Effective Pressure (BMEP) represents the average pressure acting on the piston to produce brake power and is calculated using:

$$BMEP = \frac{4\pi T}{V_d}$$

where T is torque and V_d is engine displacement.

At low speeds, BMEP is low due to poor cylinder filling and combustion. It increases to a peak in the mid-range (2000–3000 rpm) where volumetric efficiency is highest. At higher speeds, BMEP decreases due to reduced intake efficiency, increased friction, and limited combustion time, reducing effective pressure generation ([Gautam and Bhat, 2012](#)).

5 Conclusion

The engine dynamometer test successfully characterised engine performance across its operating range, providing reliable measurements of torque, brake power, specific fuel consumption, and thermal efficiency. The results showed that peak torque and minimum SFC occurred within the mid-speed range, indicating optimal volumetric efficiency and combustion conditions. Maximum brake power was achieved at higher engine speeds due to the increasing influence of rotational speed despite declining torque.

At higher speeds, performance decreased because of reduced volumetric efficiency, increased frictional losses, and limited combustion time, leading to reduced thermal efficiency and power output. These trends are consistent with established engine testing theory and validate the reliability of the experimental method ([Pulkrabek, 2004](#)).

Overall, the engine dynamometer provided a controlled and accurate environment for performance evaluation, producing data suitable for detailed analysis and comparison.

6 Evaluation

The test environment does not fully replicate real-world operating conditions, as the engine is not subjected to dynamic influences such as gear changes, drivetrain inertia, or varying road loads. Additionally, while the dynamometer accurately measures engine output, it does not account for losses that occur when the engine is installed in a complete vehicle.

Thermal effects are also significant, as both the engine and dynamometer generate heat during operation. Although cooling systems are employed to maintain stable temperatures, variations can still influence performance measurements. Furthermore, the accuracy of the results depends on proper calibration of the dynamometer, as errors in the voltage-to-torque relationship will directly affect calculated values.

The engine dynamometer system in the video provides a highly controlled and accurate method for measuring engine performance. The combination of direct torque measurement, precise load control, and comprehensive sensor integration makes it an essential tool for engine testing, calibration, and performance analysis.

7 References

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